

Spin-dependent Parton Distributions*

T. Gehrmann[†] and W.J. Stirling^{†§}[†]Department of Physics, University of Durham, Durham DH1 3LE, England.[§]Department of Mathematical Sciences, University of Durham, Durham DH1 3LE, England.

Abstract

We perform a global leading-order QCD fit to recent polarized structure function data in order to extract a consistent set of spin-dependent parton distributions. Assuming that there is no significant intrinsic polarization of the quark sea, the data are consistent with a modest amount of the proton's spin carried by the gluon, although the shape of the gluon distribution is not well constrained. We show how inelastic J/ψ production in polarized photon-hadron scattering can, in principle, provide definitive information on the shape of the gluon distribution.

Several experiments [1, 2, 3] have recently presented new measurements of the polarized deep-inelastic structure function g_1 . Combined with earlier measurements [4, 5], the data cover a broad range in x and Q^2 and provide, for the first time, detailed information on the spin-dependent parton distributions. We present here a summary of a recent analysis [6] in which we perform a leading-order QCD fit to the high- Q^2 data and extract a consistent set of parton distributions.

The fact that the measured value [3] of the integral of g_1 , $\Gamma_1^p = 0.142 \pm 0.008 \pm 0.011$, is less than the Ellis-Jaffe prediction (0.18) [7] suggests that the gluon makes a significant contribution. At leading order, we can write [8] (for 3 quark flavours)

$$g_1(x, Q^2) = \frac{1}{2} \sum_{q, \bar{q}} e_q^2 \Delta q(x, Q^2) - \frac{\alpha_s(Q^2)}{6\pi} \Delta G(x, Q^2).$$

In our model, we assume that there is no polarized sea-quark distribution at $Q^2 = 4 \text{ GeV}^2$. The only *a priori* constraints on the distributions are (i) the specification of the first moments by the sum-rule and hyperon decay data, and (ii) the requirement of positivity of the individual helicity distributions, $|\Delta f| \leq f$, ($f = q, G$).

In addition, Regge and coherence arguments can be used to fix the $x \rightarrow 0$ behaviour. Unfortunately neither the neutron [1] nor deuteron [2] g_1 data are precise enough to constrain the Δd distribution: the fit is dominated by g_1^p which depends mainly on Δu . For consistency, we choose the same $\Lambda_{\text{LO}}^{(4)} = 177 \text{ MeV}$ and $Q_0 = 2 \text{ GeV}$ values as [9], and similar starting parametrizations at $Q^2 = Q_0^2$:

$$\begin{aligned} x\Delta u_v &= \eta_u A_u x^{a_u} (1-x)^{b_u} (1 + \gamma_u x) \\ x\Delta d_v &= \eta_d A_d x^{a_d} (1-x)^{b_d} (1 + \gamma_d x) \\ x\Delta \bar{q} &= 0 \quad (q = u, d, s, c) \\ x\Delta G &= \eta_G A_G x^{a_G} (1-x)^{b_G} (1 + \gamma_G x) \end{aligned}$$

with normalization factors A_f ($f = q, G$) to ensure that $\int_0^1 dx \Delta f(x, Q_0^2) = \eta_f$: We impose a cut $Q^2 > 4 \text{ GeV}^2$ on the data to suppress higher-twist contributions. The fit to the g_1^p structure function data from SLAC [4], EMC [5] and SMC [3] is shown in Fig. 1 and the resulting parameters are listed in Table 1. The shape of the gluon distribution is not well constrained. In the fit shown in Fig. 1, $\gamma_G = 0$ (the set A gluon) has been chosen. Equally good fits can be obtained with other values. To span the range allowed by positivity, we define two other sets which have $\gamma_G = 18.0$ (set B) and $\gamma_G = -3.5$ (set C), with the other parameters fitted to the data. Fig. 2

* Presented by WJS at the 27th International Conference on High Energy Physics, Glasgow, July 1994

Parameter	Value	Comments
η_u	0.848	$\eta_u = 2F$
b_u	3.64	= unpolarized b_u
a_u	0.46	fitted
γ_u	18.36	fitted
η_d	-0.294	$\eta_d = F - D$
b_d	4.64	= unpolarized b_d
a_d	0.46	= a_u (Regge)
γ_d	18.36	= γ_u (constrained)
η_G	1.971	from Γ_1^p
b_G	7.44	fitted
a_G	1.0	coherence arguments
γ_G	0.0	constrained

Table 1. Parameters for the set A partons

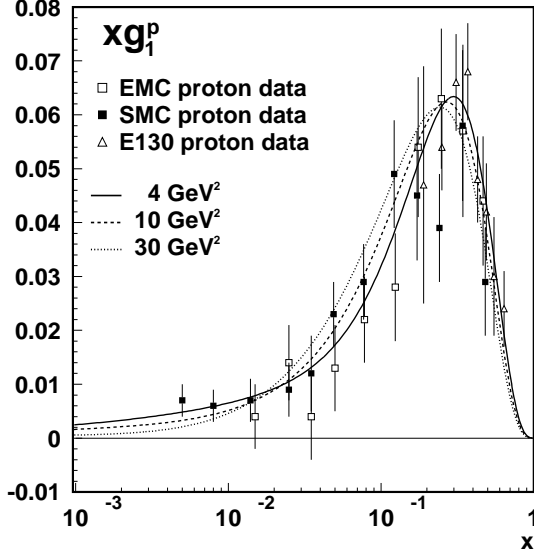


Figure 1. Fit to the g_1^p structure function with set A gluon

shows the set A gluon, quark-singlet, u -valence and d -valence distributions at Q_0^2 obtained from the fit. For comparison, the unpolarized distributions of Ref. [9] are also shown. Note that perturbative evolution generates a polarized sea distribution for $Q^2 > Q_0^2$. However in the range of Q^2 relevant to the structure function measurements the polarized sea is small in comparison to Δu and Δd . This appears to be consistent with the preliminary measurements of $\Delta \bar{q}$ from inclusive hadron production, reported by SMC at this conference [10].

Inelastic J/ψ production in polarized photon-nucleon scattering provides a possible method of measuring ΔG [11]. The cross section $d\Delta\sigma^{\gamma N}/dp_T^2 dz$ (where $z = E_{J/\psi}/E_\gamma$) is proportional to ΔG in leading order. The asymmetry $\mathcal{A}(z)$, defined by integrating over $p_T^2 > 0.25 \text{ GeV}^2$, is shown in Fig. 3 for the three gluons.

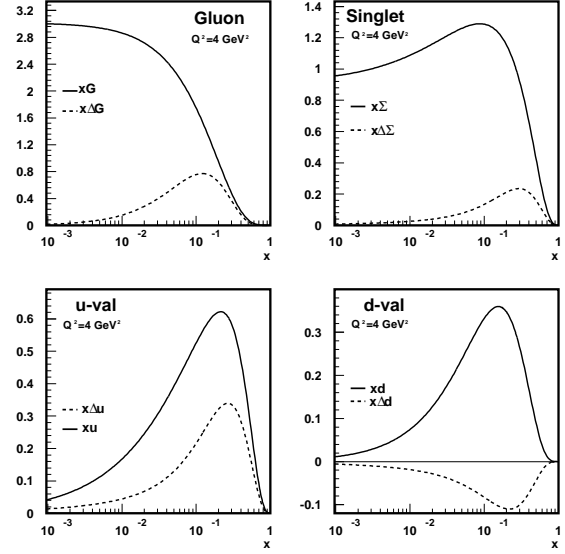


Figure 2. The polarized gluon (set A), quark singlet, u -valence and d -valence distributions at $Q_0^2 = 4 \text{ GeV}^2$ obtained from the fit to the deep inelastic scattering data.

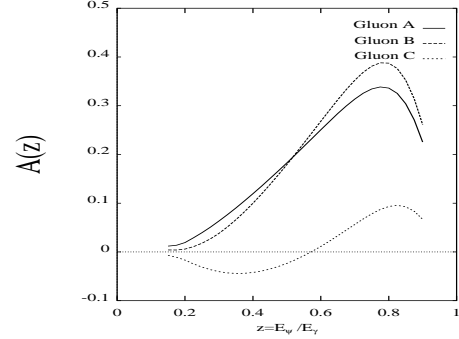


Figure 3. The asymmetry $\mathcal{A}(z)$ predicted by the different gluon distributions, for a photon beam of energy $E_\gamma = 45 \text{ GeV}$ on a stationary proton target [12].

References

- [1] SLAC-E142 collaboration: D.L. Anthony *et al.*, Phys. Rev. Lett. **71** (1993) 959.
- [2] SMC: B. Adeva *et al.*, Phys. Lett. **B302** (1993) 553.
- [3] SMC: D. Adams *et al.*, Phys. Lett. **B329** (1994) 399.
- [4] SLAC-Yale collaboration: M.J. Alguard *et al.*, Phys. Rev. Lett. **37** (1976) 1261; G. Baum *et al.*, Phys. Rev. Lett. **45** (1980) 2000; **51** (1983) 1135.
- [5] EMC: J. Ashman *et al.*, Nucl. Phys. **B328** (1989) 1.
- [6] T. Gehrmann and W.J. Stirling, Durham preprint DTP/94/38 (1994), to be published in Zeit. Phys. **C**.
- [7] J. Ellis and R.L. Jaffe, Phys. Rev. **D9** (1974) 1444, erratum **D10** (1974) 1669.
- [8] G. Altarelli and G.G. Ross, Phys. Lett. **B212** (1988) 391.
- [9] J.F. Owens, Phys. Lett. **B266** (1991) 126.
- [10] SMC: J. Nassalski, these proceedings.
- [11] J.Ph. Guillet, Z. Phys. **C39** (1988) 75.
- [12] V. Breton, *Measurement of ΔG by J/ψ Photoproduction at SLAC*, SLAC proposal, 1994.